

Tropical Cyclone Forecast Products Derived From the Advanced Microwave Sounding Unit

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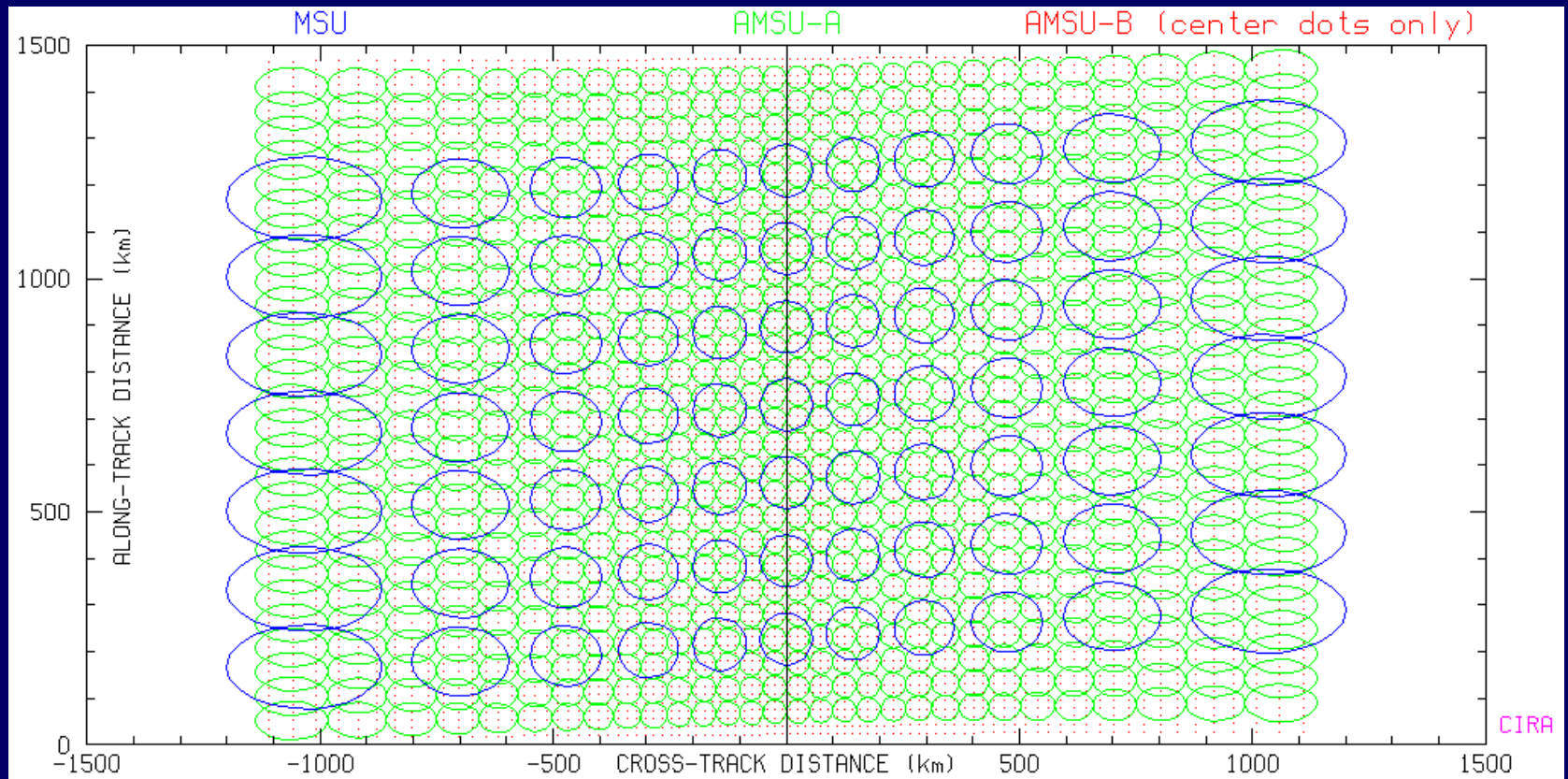
AMSU Instrument Properties

- AMSU-A1
 - 13 frequencies 50-89 GHz
 - 48 km maximum resolution
 - Vertical temperature profiles 0-45 km
- AMSU-A2
 - 2 frequencies 23.8, 31.4 GHz
 - 48 km maximum resolution
 - Precipitable water, cloud water, rain rate
- AMSU-B
 - 5 frequencies: 89-183 GHz
 - 16 km maximum resolution
 - Water vapor soundings

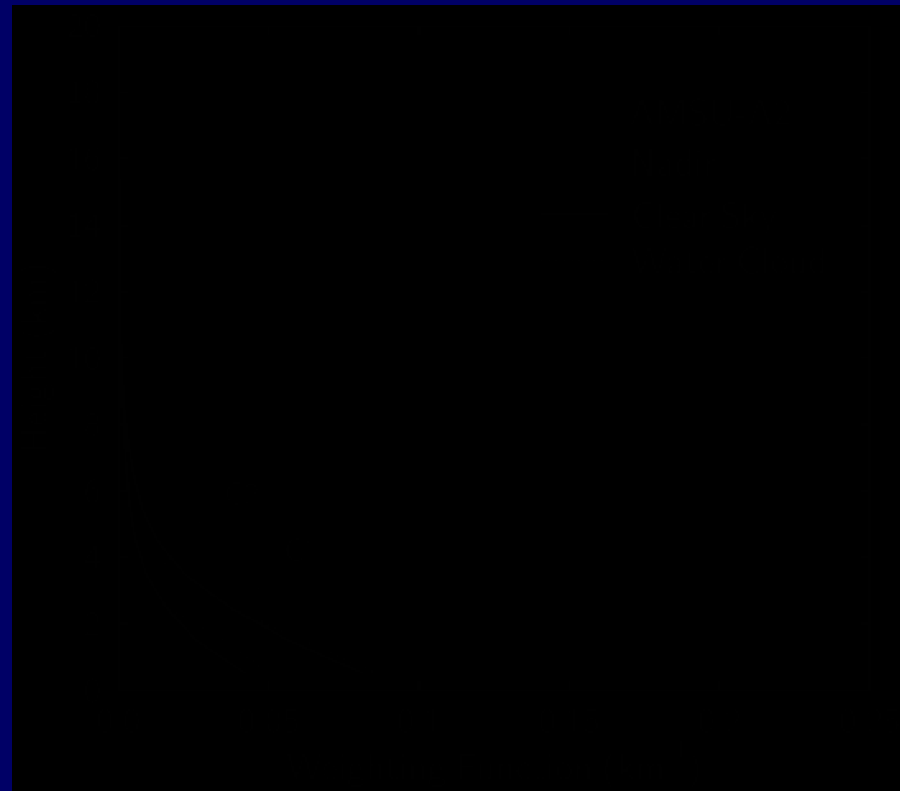
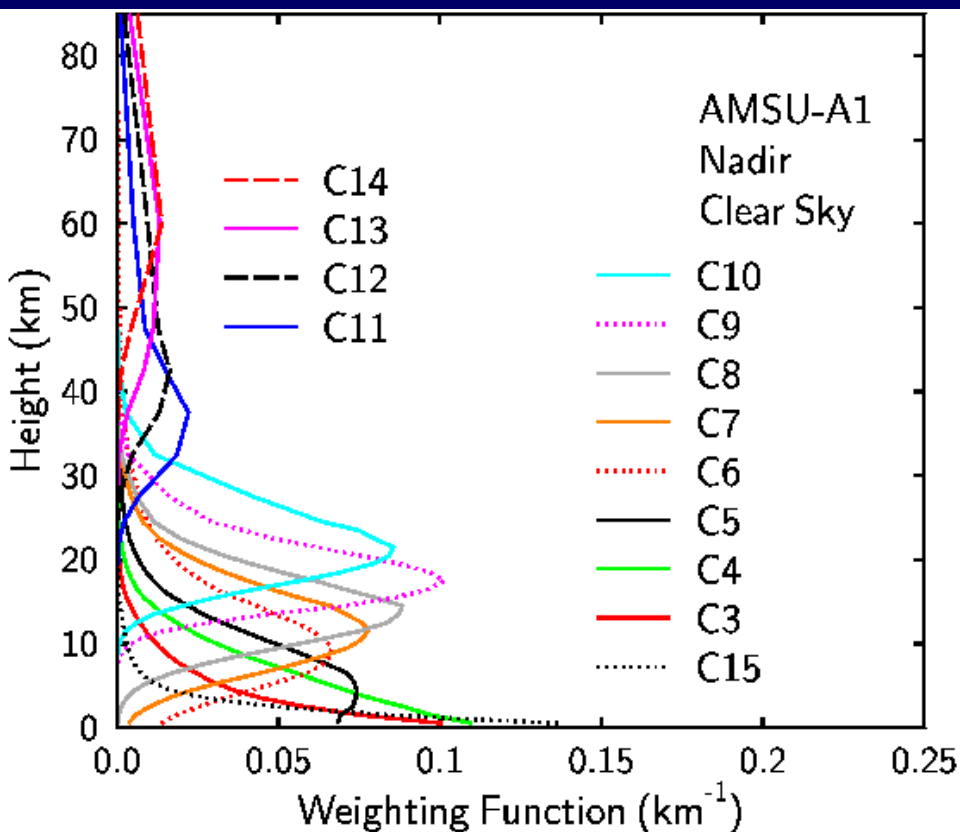
**NOAA - 15, Launched May
13, 1998**



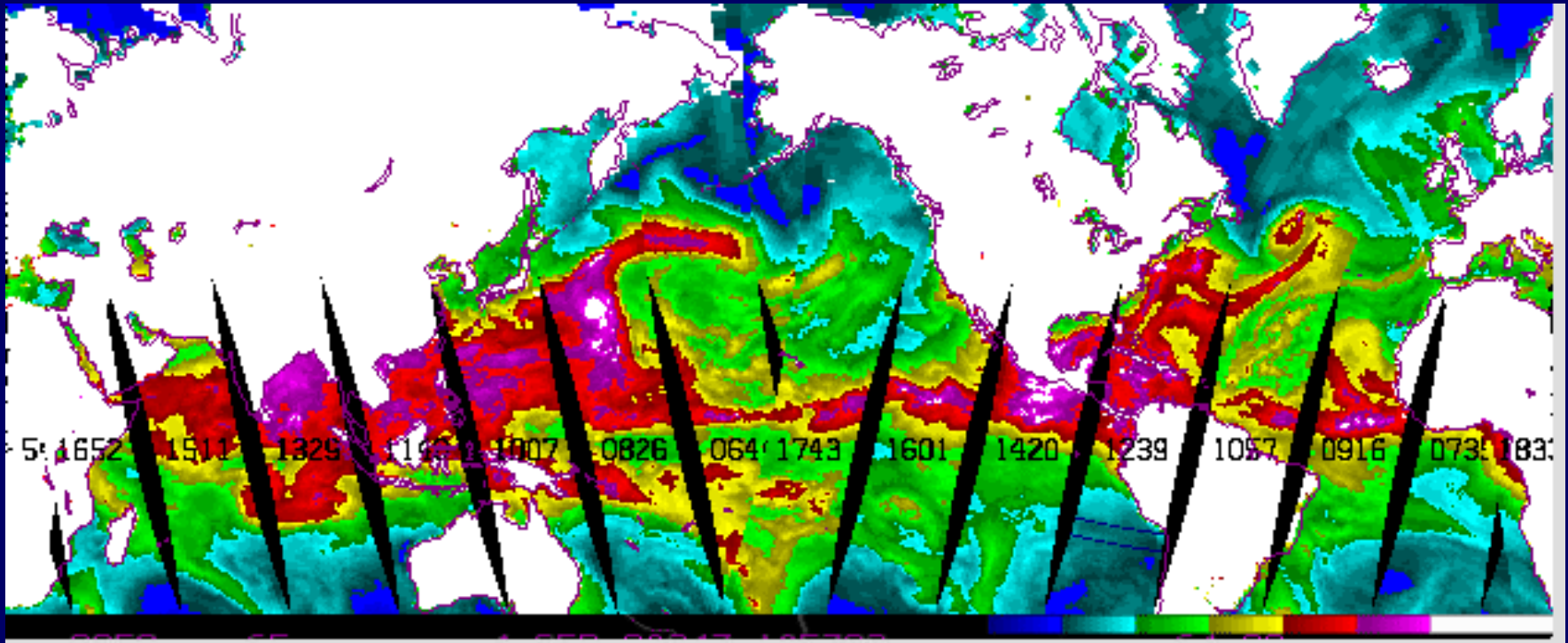
Horizontal Resolution: AMSU-A vs. MSU



Vertical Weighting: AMSU-A



Typical AMSU Data Coverage (NOAA-15)

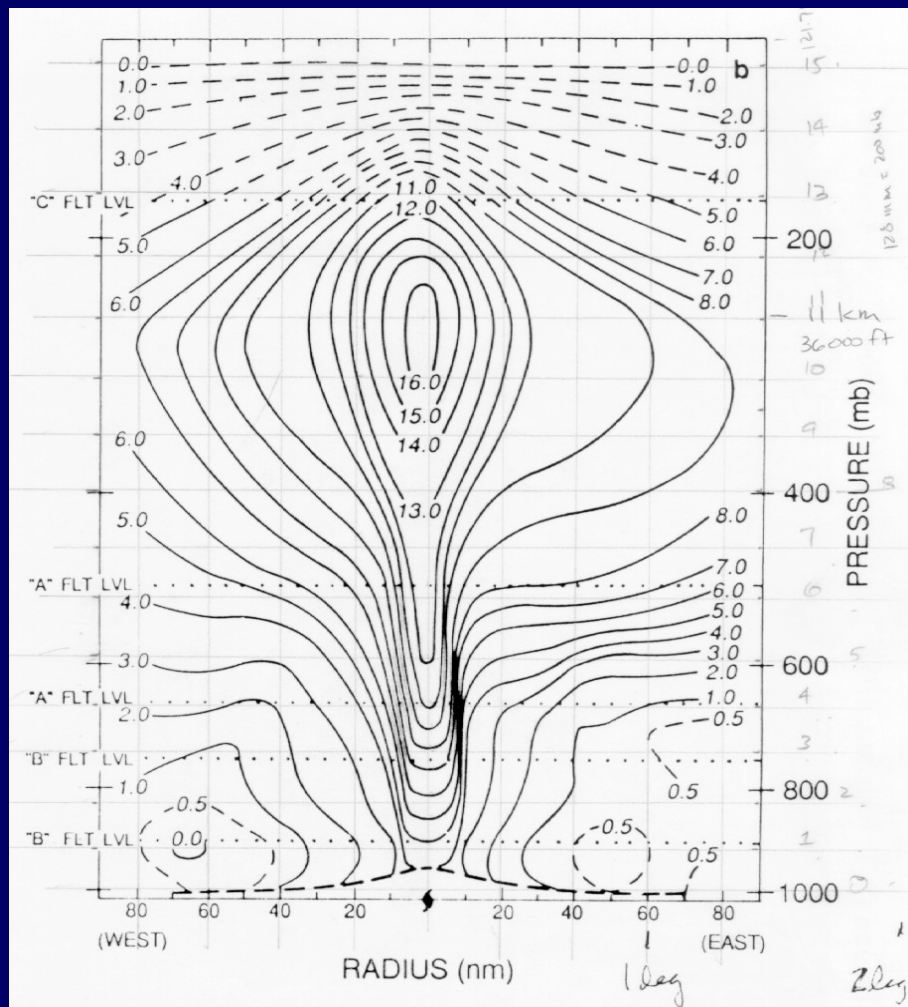
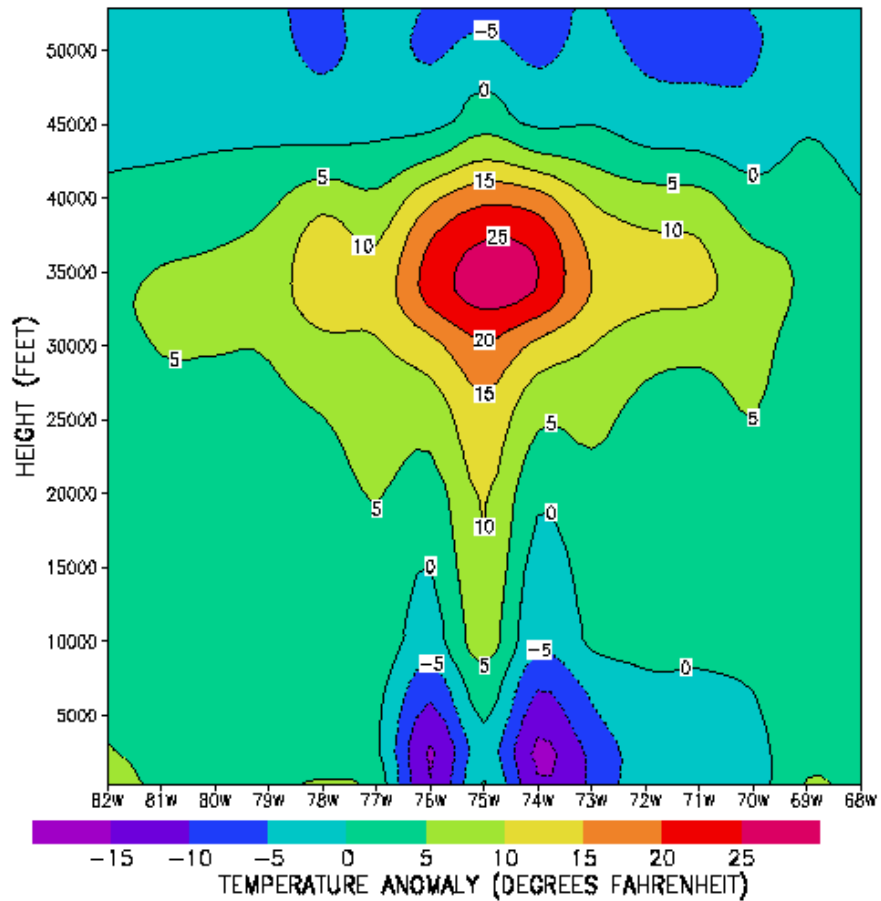


Total Precipitable Water

Tropical Cyclone Applications

- Center Fix - Location of min surface pressure
- Intensity Estimation - From r,z analyses
- Size Estimation - From r,z analyses
- Asymmetric vortex structure - From x,y,p winds
- Steering flow - From x,y,P winds
- Impact on data assimilation

HURRICANE BONNIE TEMPERATURE CROSS-SECTION



Temperature Retrieval Algorithm

- 15 AMSU-A channels included
- Radiances adjusted for side lobes before conversion to brightness temperatures (BT)
- BT adjusted for view angle
- Statistical algorithm converts from BT to temperature profiles
- 40 vertical levels 0.1-1000 mb
- RMS error 1.0-1.5 K compared with rawinsondes

AMSU-A Moisture Algorithms

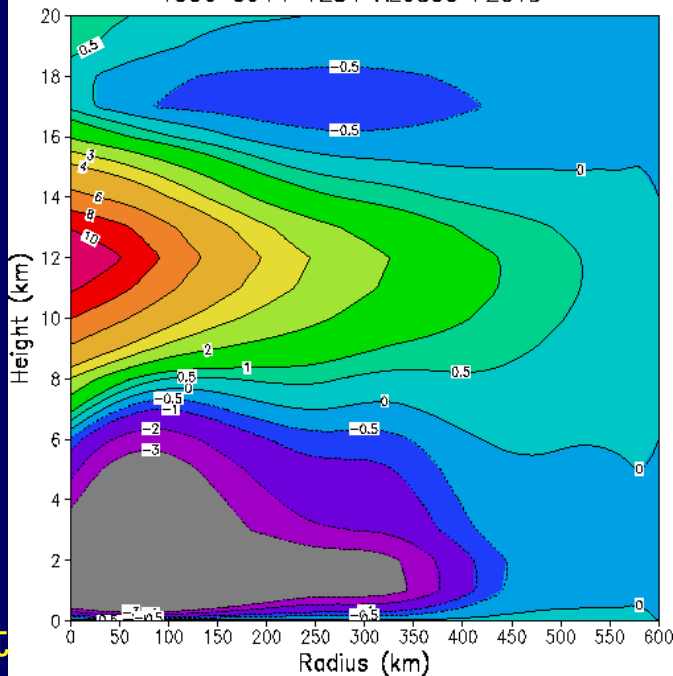
- **Total Precipitable Water (TPW)**
 - $TPW = \cos(Z) * f[T_B(23.8), T_B(31.4)]$
- **Cloud Liquid Water (CLW)**
 - $CLW = \cos(Z) * g[T_B(23.8), T_B(31.4)]$
- **Rain Rate (RR)**
 - $RR = 0.002 * Q^{1.7}$, where Q is clw.

T Correction for Liquid Water Attenuation

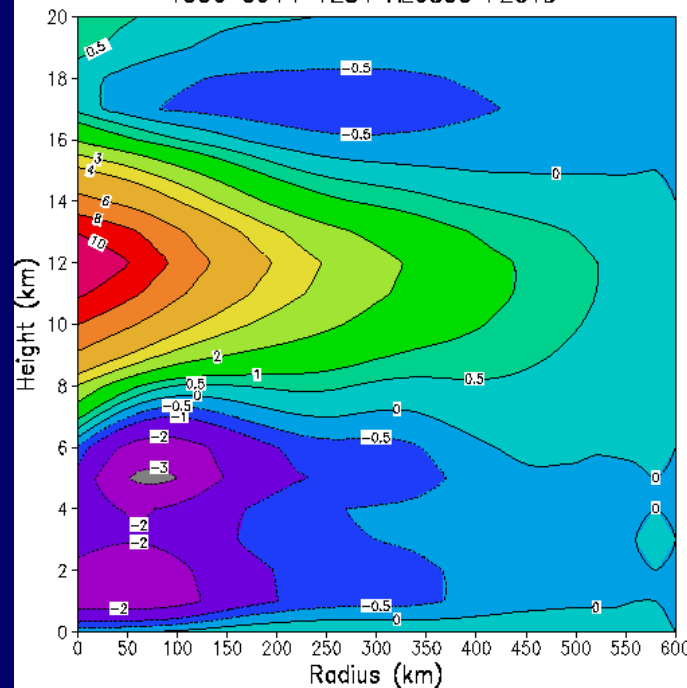
- Attenuation severely degrades T, Z, wind retrievals
- Two-step correction procedure:
 - 300-920 mb, linear regression between CLW and T, apply linear correction at each pressure level
 - Reduce magnitude of cold anomaly for $P > 600$ mb in analysis domain

T_a

Temp Anomaly (C)
1999 0914 1254 AL0899 FLOYD



Temp Anomaly (C)
1999 0914 1254 AL0899 FLOYD



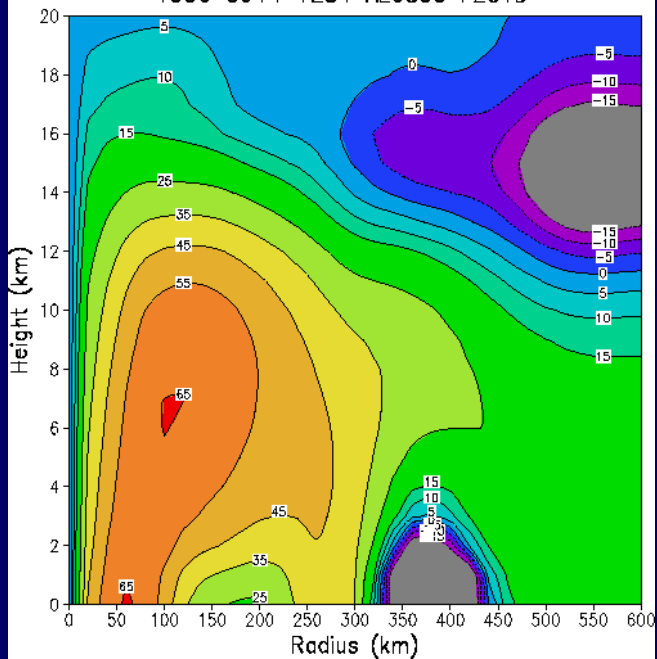
T_a

Without
Correction

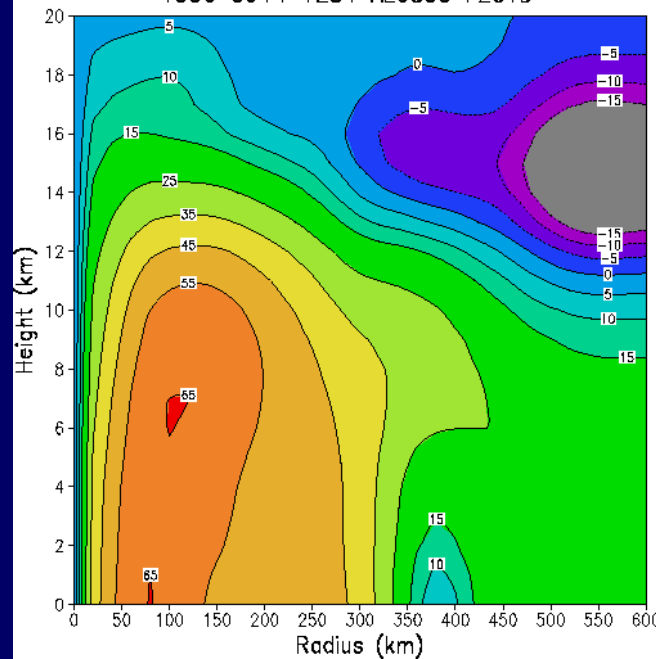
With
Correction

V

AMSU Grad Wind (kt)
1999 0914 1254 AL0899 FLOYD



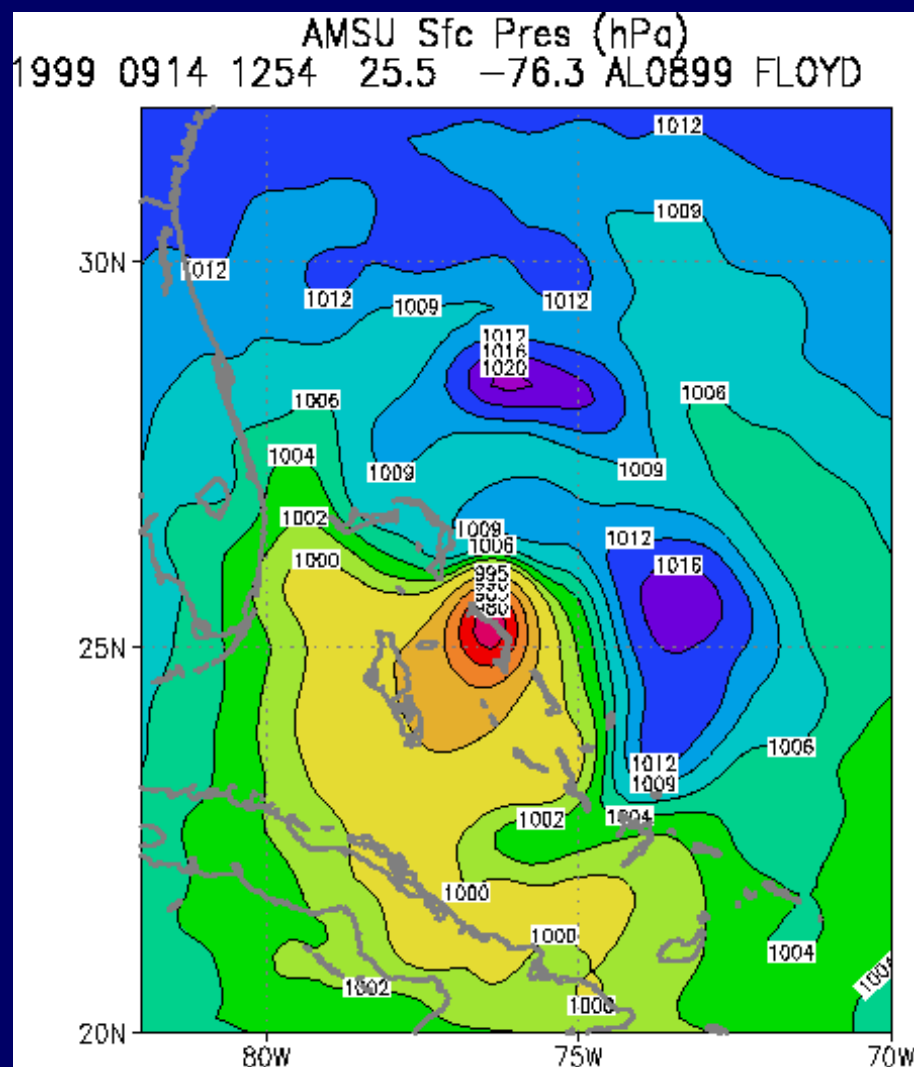
AMSU Grad Wind (kt)
1999 0914 1254 AL0899 FLOYD



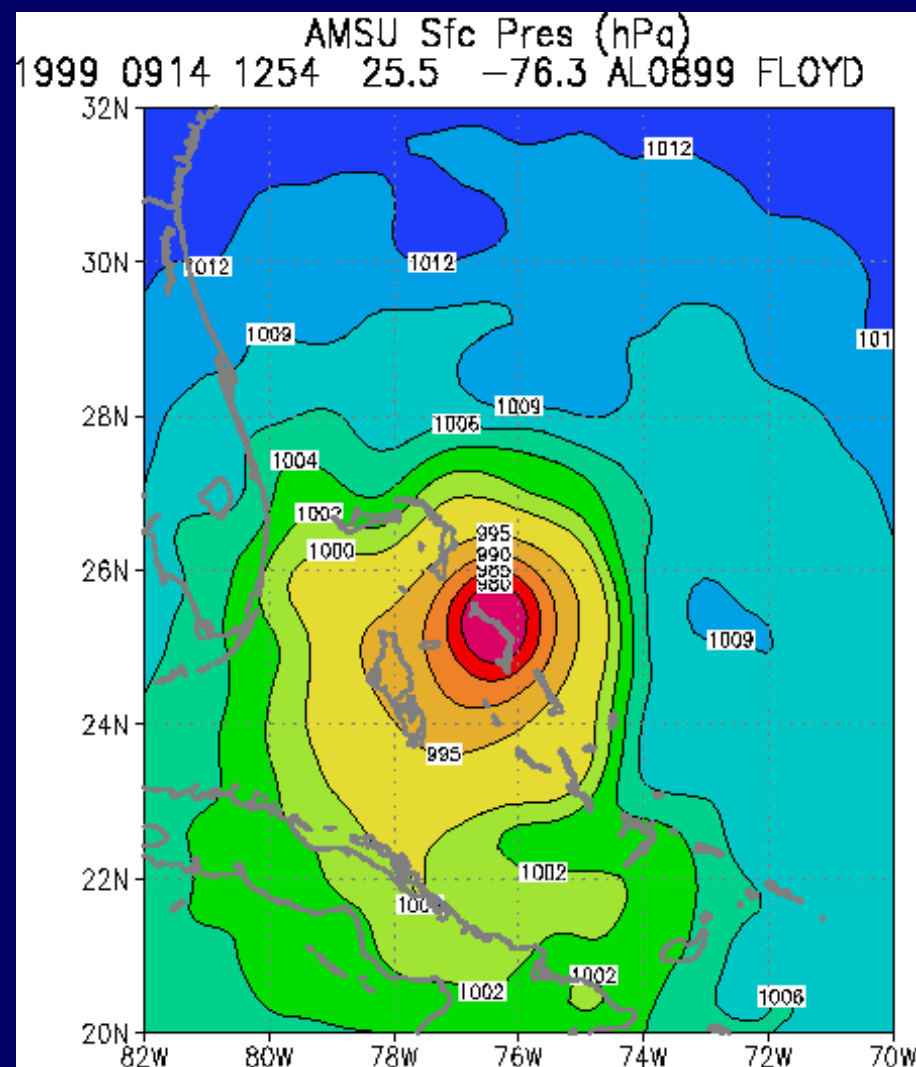
V

AMSU Surface Pressure for Floyd 14 Sept

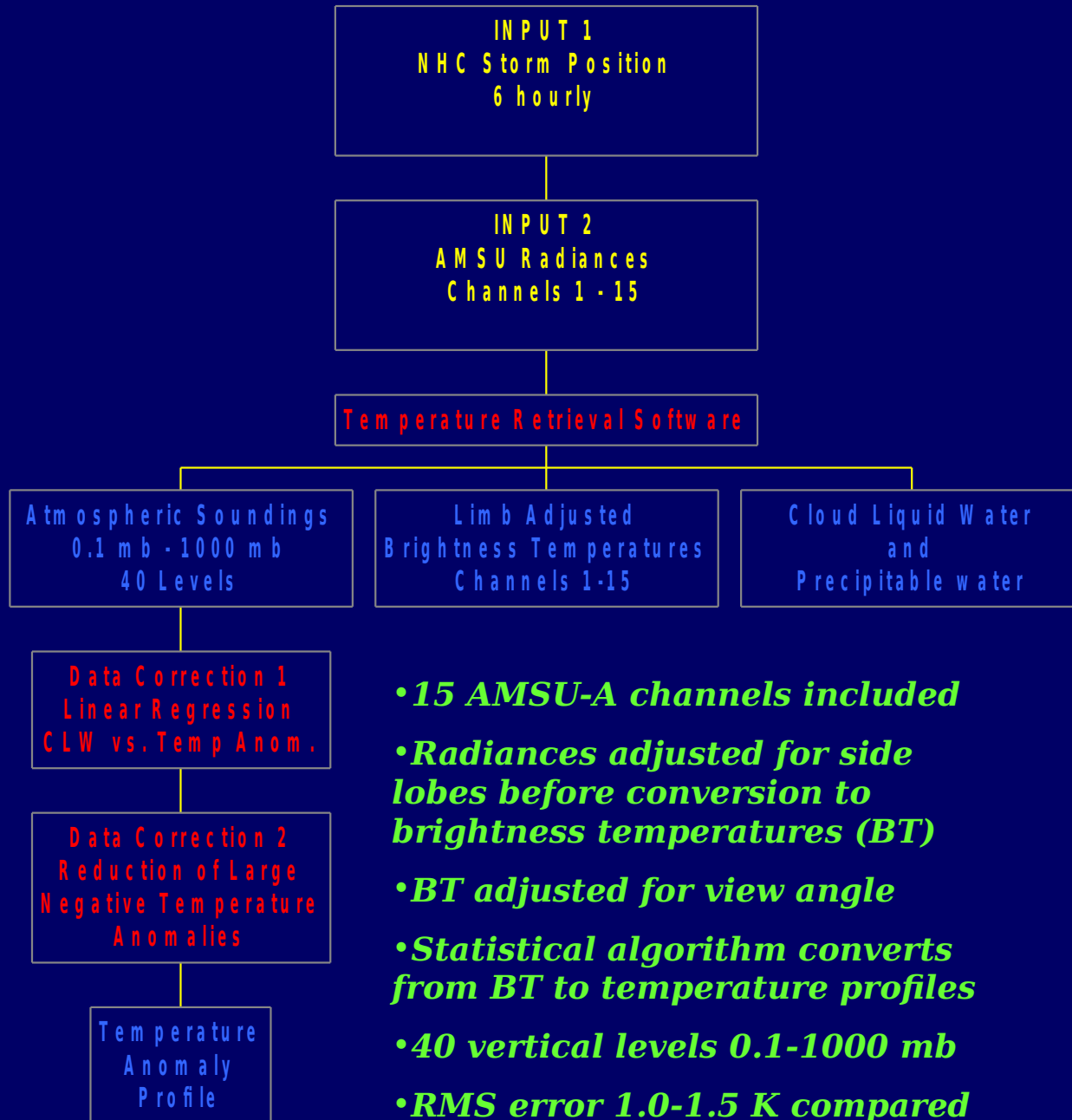
Uncorrected

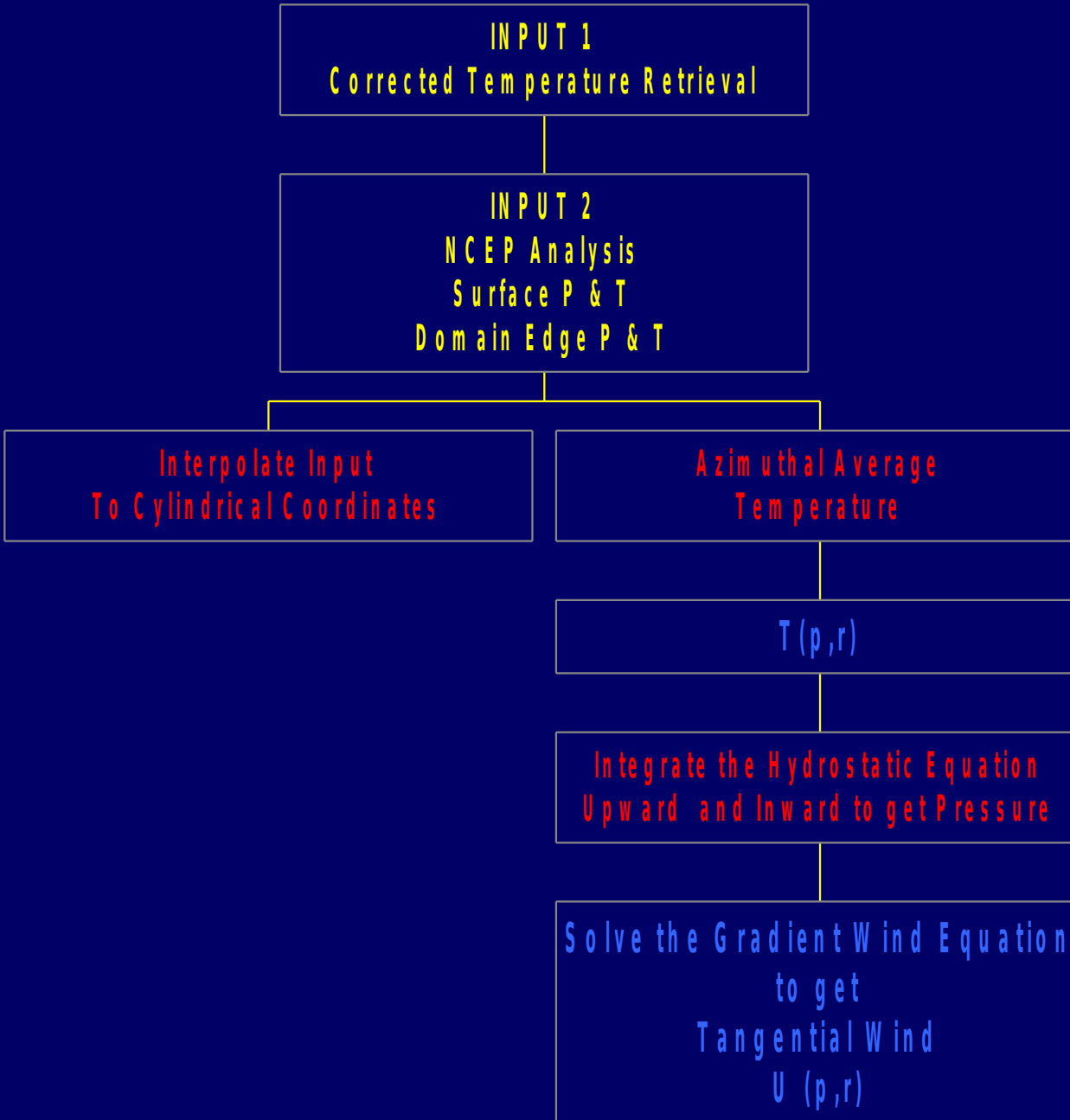


Corrected



DATA PROCESSING





• **Neglect virtual temperature effects, interpolate T to evenly spaced analysis grid**

• **Start with NCEP T_s , P_s on analysis boundary**

• **Integrate AMSU T upwards to 50 mb on boundaries to give $Z_b(P)$**

• **Assume no curvature at 50 mb ($\nabla^2 Z = 0$)**

• **Integrate AMSU T downwards (50 mb to surface) in domain interior**

– $Z(x,y,P)$, $P_s(x,y)$
or $Z(r,P)$, $P_s(r)$

– **Calculate gradient wind from $Z(r,P)$**

• **Alternate procedure: Start with NCEP Z at 100 mb**

Estimates of Intensity (V_{\max} , P_{\min}) and of R_{35} , R_{50} and R_{65}

- Using the retrieved temperature profile and gradient winds
- Multiple linear regression is employed to estimate these parameters.

Intensity Estimates

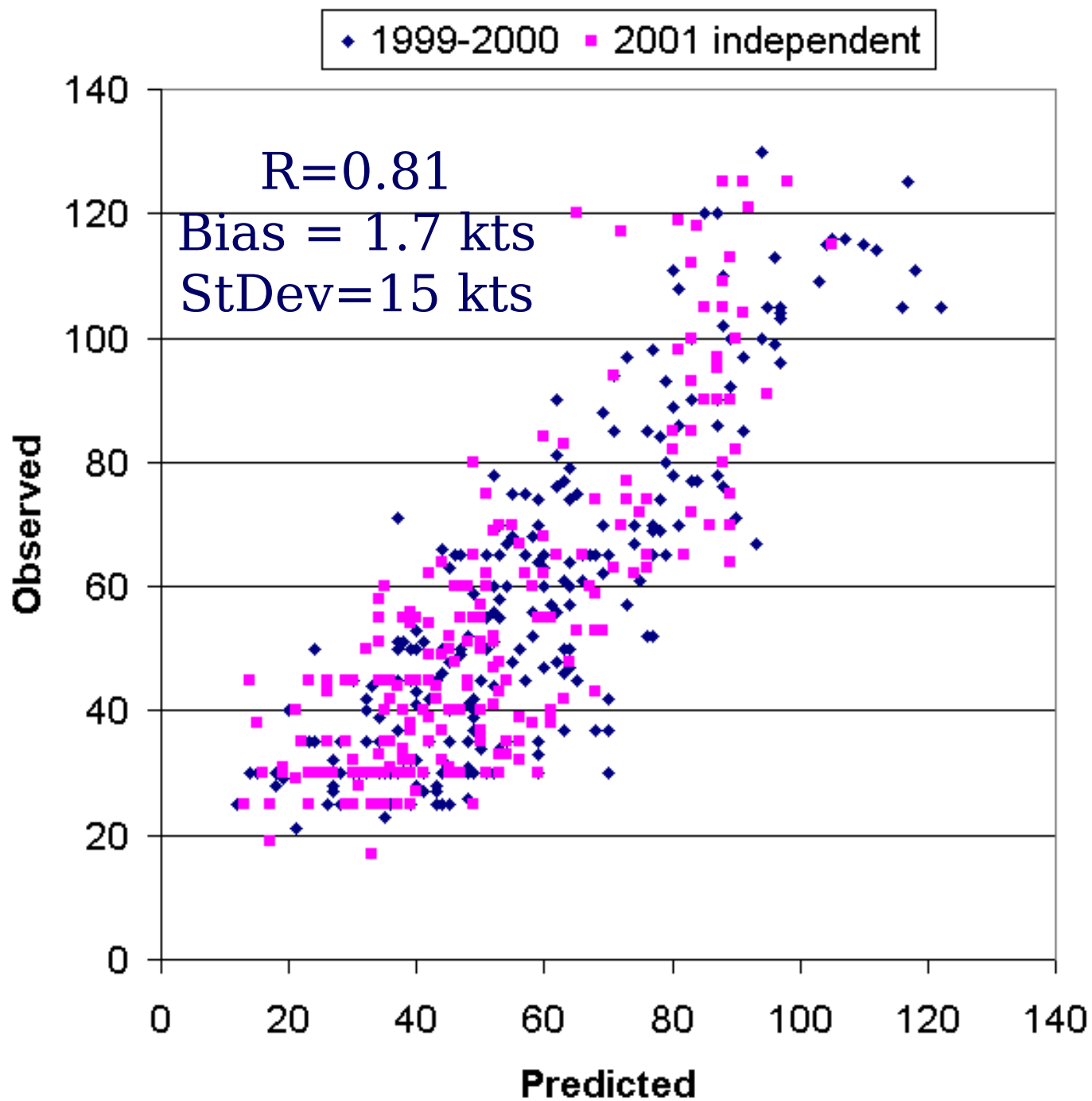
- 19 Predictors derived from the temperature/wind retrieval are regressed against the best track estimate of V_{max} and lowest SLP.

19 potential predictors

1. Analyzed pressure at $r=0$
2. $R=600$ to $r=0$ Pressure drop at $z=0\text{km}$
3. Pressure drop at $z=3\text{km}$
4. $R=0$ max T anomaly
5. Height of max T anom.
6. Swath spacing
7. Max wind at $z=0\text{ km}$
8. Radius of max wind $z=0\text{km}$
9. Max wind at $z=3\text{km}$
10. Radius of max wind $z=3\text{km}$
11. 0-250 km avg. wind at $z=0\text{ km}$
12. 0-250 km avg. wind at $z=3\text{ km}$
13. 0-250 km avg. wind at $z=5\text{ km}$
14. 250-500 km avg. wind, $z=0\text{ km}$
15. 250-500 km avg. wind, $z=3\text{ km}$
16. 250-500 km avg. wind, $z=5\text{ km}$
17. $R=0$ to $r=100\text{k}$ avg. CLW
18. Percent CLW $r=0$ to 300 exceeding 0.5
19. Storm latitude

Vmax Results

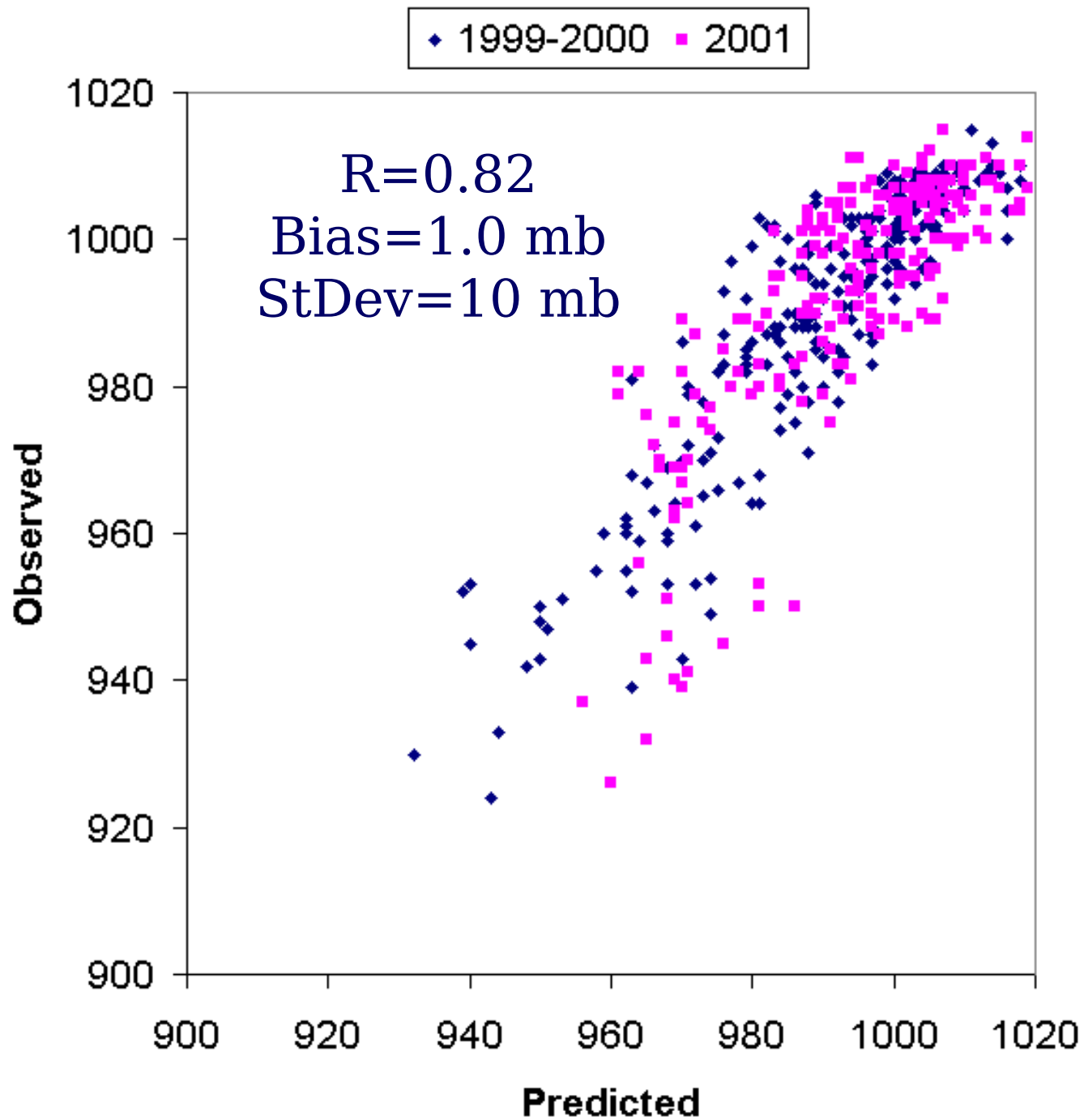
- 7 predictors
 1. R=0 to 600 pres. Drop at z=3 km
 2. Radius of max wind at z=3 km
 3. 0-250 km mean wind at z=3 km
 4. 0-250 km mean wind at z=5 km
 5. 250-500 km mean wind at z=0 km
 6. 250-500 km mean wind at z=5 km
 7. R=0 to 100 km avg. CLW
- Developmental Data
 - R = 0.86
- Independent
 - R = 0.81
 - Bias = -1.7 knots
 - Stdev Error = 15 knots



Minimum SLP Results

- 7 predictors
 1. Radius of max wind at $z=3$ km
 2. 0-250 km mean wind at $z=3$ km
 3. 0-250 km mean wind at $z=5$ km
 4. 250-500 km mean wind at $z=0$ km
 5. 250-500 km mean wind at $z=5$ km
 6. $R=0$ to 100 km avg. CLW
 7. Latitude
- Developmental Data
 - $R = 0.90$
- Independent
 - $R = 0.82$
 - Bias = 1.0 mb
 - Stdev Error = 10 mb

SLP



Estimation of Wind Radii

- 20 potential predictors are used to predict the mean radii of 35, 50, and 65 knot winds if they exist.
- Asymmetries are accounted for by a simple relationship

$$V(r, \theta) = (V_m - a) \left(\frac{r_m}{r} \right)^x + a \cos(\theta)$$

- Actual mean radii are estimated using

$$\bar{r} = \frac{r_m}{2\pi} \int_0^{2\pi} \left[\frac{V_m - a}{V - a \cos(\theta)} \right]^{1/x} d\theta$$

But are solved using since all radii rarely exist.

Cost Function and Variational Analysis

- Cost Function (thing to minimize iteratively)

$$C(r_m, x) = \frac{(r_{34} - R_{34})^2}{\sigma_{34}^2} + \frac{(r_{50} - R_{50})^2}{\sigma_{50}^2} + \frac{(r_{64} - R_{64})^2}{\sigma_{64}^2} + \lambda_x \frac{(x - x_c)^2}{\sigma_x^2} + \lambda_{rm} \frac{(r_m - r_{mc})^2}{\sigma_{rm}^2}$$

Last two terms are used to constrain the results close to climatology (penalty terms)
– climatological r and x are functions of intensity.

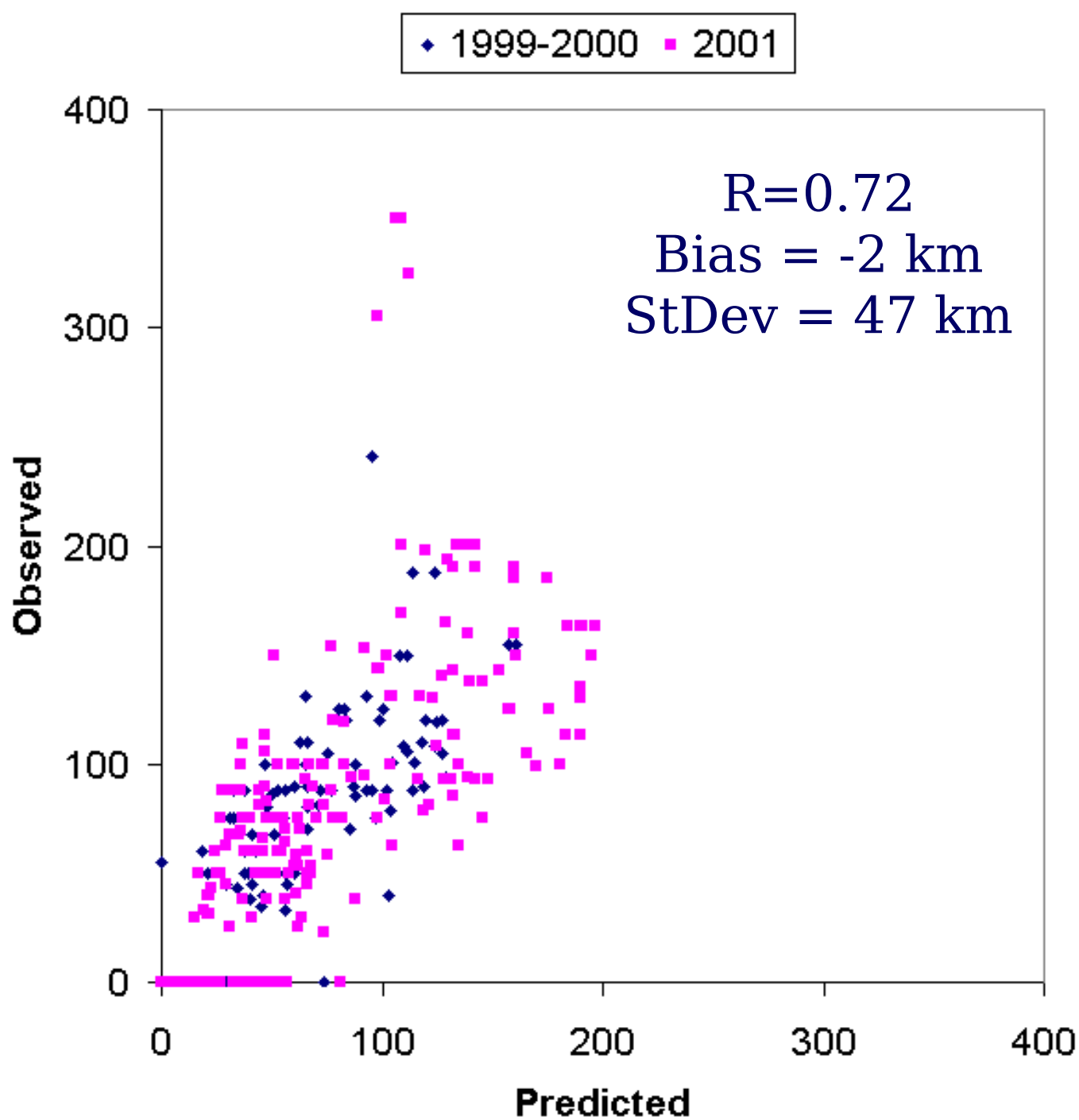
20 potential predictors

1. Analyzed pressure at $r=0$
2. $R=600$ to $r=0$ Pressure drop at $z=0\text{km}$
3. Pressure drop at $z=3\text{km}$
4. $R=0$ max T anomaly
5. Height of max T anom.
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7. Max wind at $z=0\text{ km}$
8. Radius of max wind $z=0\text{km}$
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17. $R=0$ to $r=100\text{k}$ avg. CLW
18. Percent CLW $r=0$ to 300 exceeding 0.5
19. Storm latitude
20. Storm Intensity

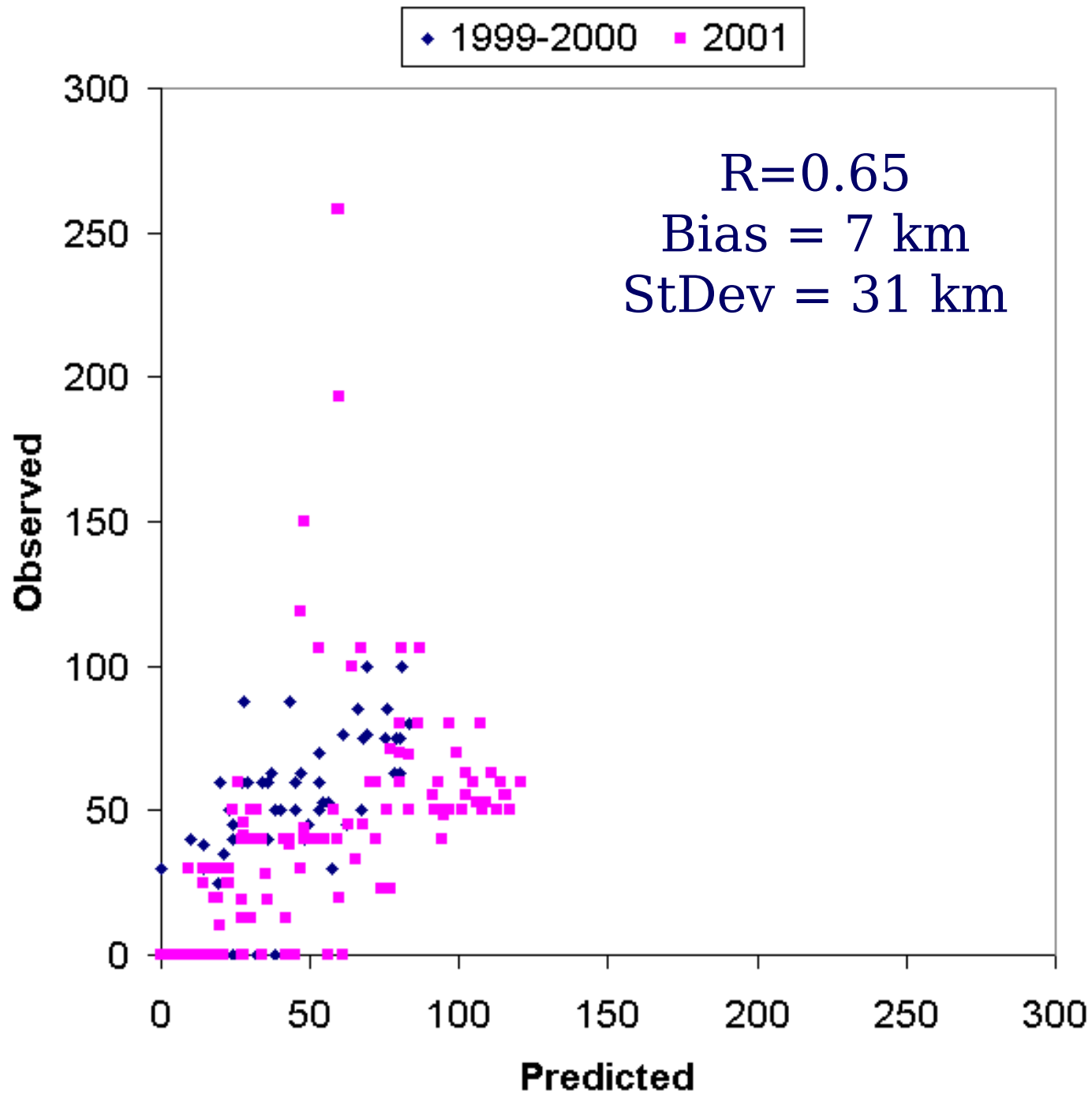
Wind Radii Results

- 5 Predictors
 1. R= 600 to 0 km
Pressure drop at z=3km
 2. 0-250 km avg. wind at
z=3 km
 3. R=0 to r=100k avg.
CLW
 4. Storm latitude
 5. Storm Intensity
- Developmental Data
R = 0.85, 0.87, and
0.88 at R35, R50,
and R65
- Independent
R = 0.72, 0.65, and
0.85
Bias = -2, 7, and 8 nmi
Stdev Error = 47, 31,
10 nmi

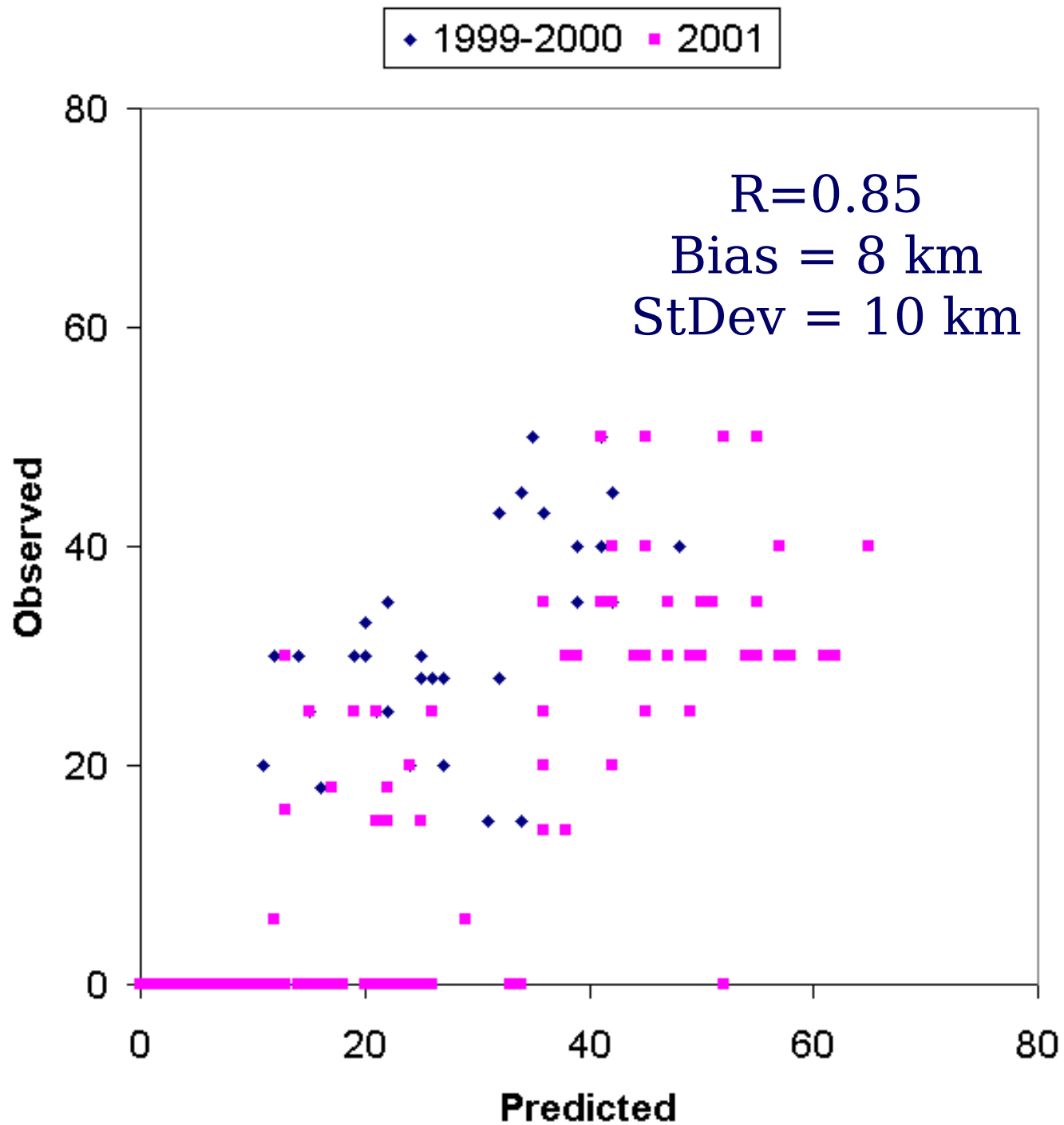
R35



R50



R65



Hurricane Michelle 1930 UTC 02 Nov 2001

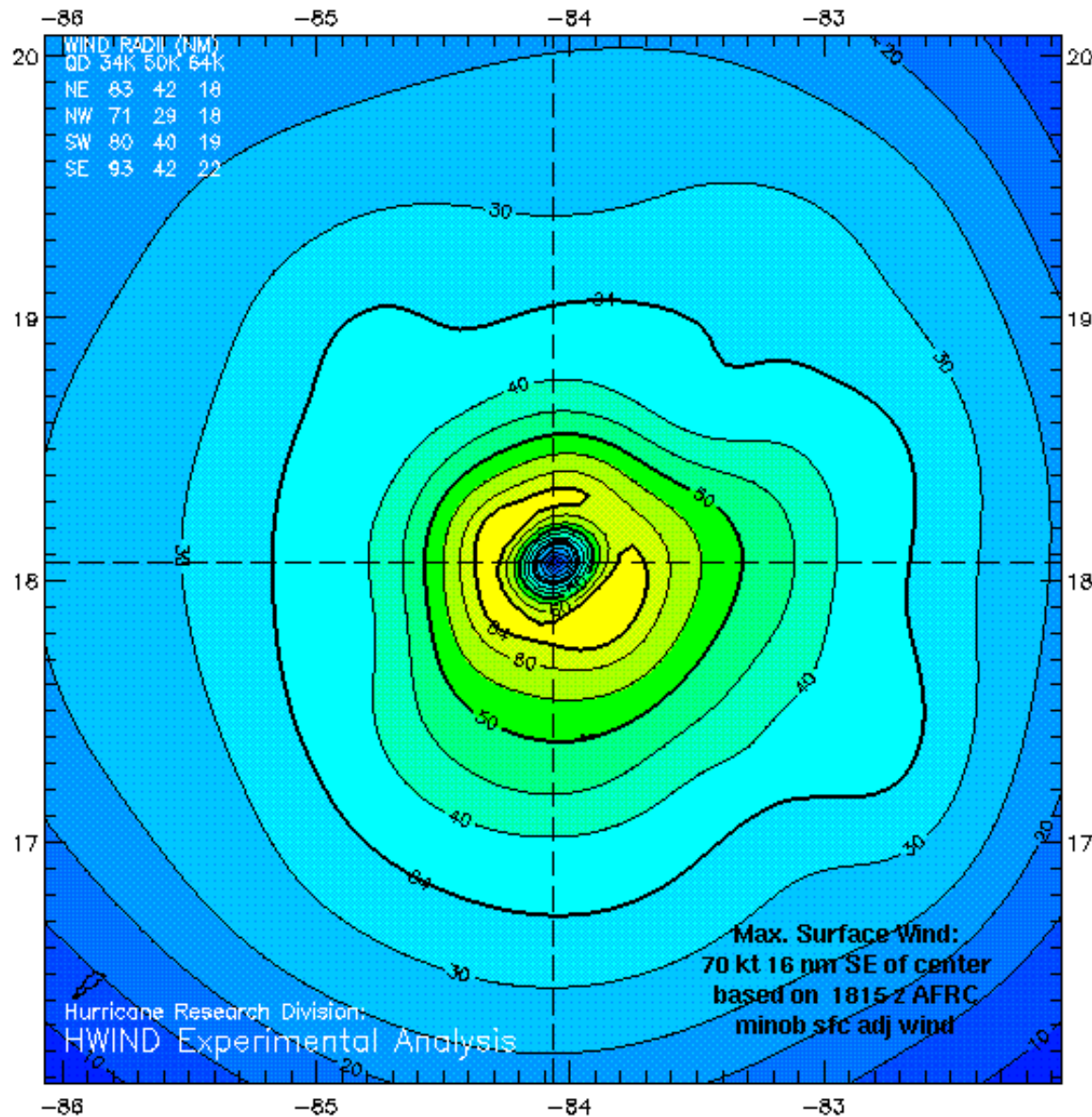
Max. 1-min sustained surface winds (kt)

Analysis based on AFRC C-130 850 mb winds adj. to sfc: 1732 - 1929 z;

6 GPS dropsondes: 1808 - 1849 z; Ship reports: 1500 - 1900 z;

CIMSS GOES low-level cloud-drift winds adj. to sfc: 1600 z;

1930 z wind center extrapolated from 1811 z AFRC fix using 360° @ 3 kt; mslp: 969 mb



Aircraft

Example

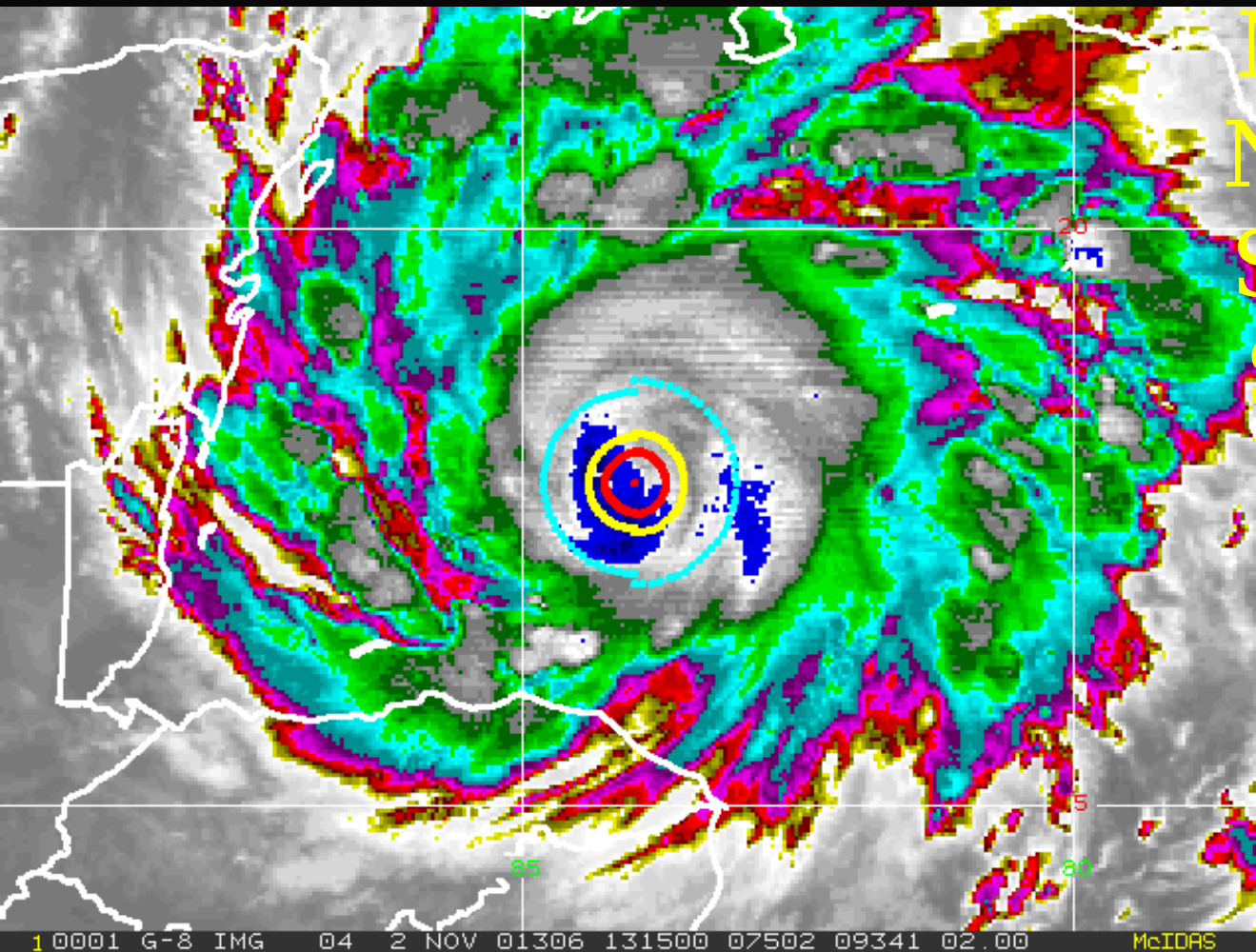
NE 83 42 18

NW 71 29 18

SW 80 40 19

SE 93 42 22

AMSU



NE 98 48 30
NW 87 44 28
SW 87 44 28
SE 98 48 30

Example in the West Pacific

CIRA/NESDIS Experimental AMSU-A TC Intensity/Size Estimation

Tropical Cyclone XXXX WP052002

Current date/time: 2002 0517 1205 UTC

ATCF file date/time: 2002 0517 0600 UTC

AMSU swath date/time: 2002 0517 0438 UTC

Minimum Sea-Level Pressure: 984 hPa

Maximum Surface Winds: 68 kt

34 kt wind radii (NE,SE,SW,NW): 79 58 52 70 nmi

50 kt wind radii (NE,SE,SW,NW): 37 0 0 34 nmi

64 kt wind radii (NE,SE,SW,NW): 0 0 0 0 nmi

AMSU-retrieved max wind radius: 31 nmi

Storm center is 375 km from AMSU swath center

0-300 km is optimal

300-600 km is adequate

>600 km is marginal

AMSU data is -2 hr from time of ATCF input

ATCF File Input:

WP052002 0517 0600 UTC

Storm lat,lon (t = 0 hr): 13.50 140.00

Storm lat,lon (t = -12 hr): 12.80 141.90

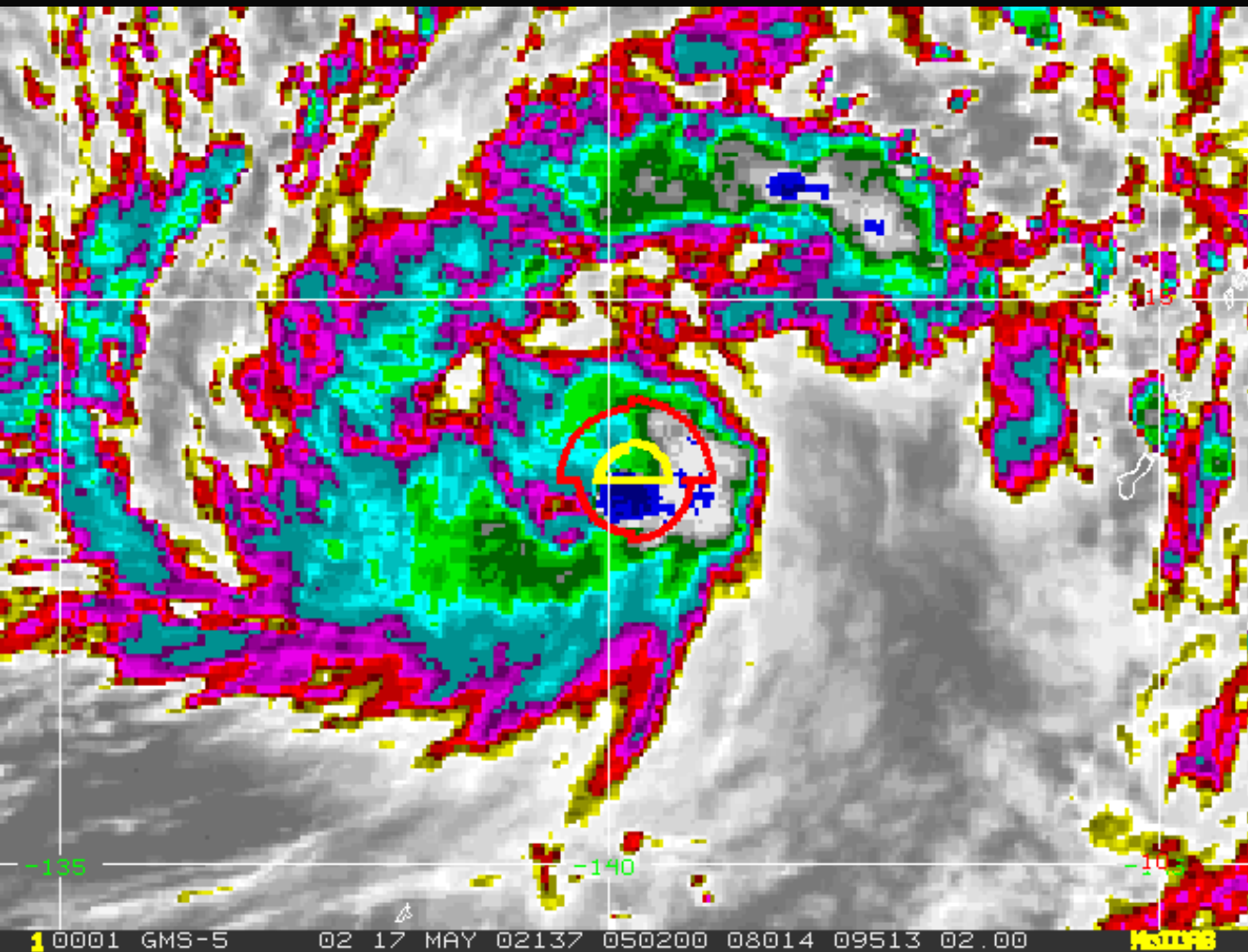
Storm lat,lon (t = -2 hr): 13.42 140.22 (AMSU swath time)

Storm max winds (ATCF): 55 kt

Storm heading: 290 deg

Storm translation speed: 12

AMSU



NE 79 37 0
NW 70 34 0
SW 52 0 0
SE 58 0 0

TWC = 55 knots AMSU = 68 knots, 984 n

Where do we go from here?

- Re-derive coefficients using 2001 data.
- JHT at NHC, FTP results to NHC at the synoptic hours
- Run the W. Pacific cases.. – email/FTP to JTWC?, Post on PZAL?
- Possibly installing the intensity algorithms at NESDIS/SAB
- NOAA-17, Aqua?

Questions/Comments?

Example

HURRICANE FLOYD

On 14 September 1999 at 12 UTC Hurricane Floyd was located at 25.4 N, 76.20 W with maximum sustained winds of 130 kts (~150 mph) and had a minimum surface pressure of 929 mb. The storm had just past the island of Eleuthera in the central Bahamas.

